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Integrated Science Instrument Module (ISIM): Project Overview & Detector Requirements

Presentation to the NGST Detector Workshop
20 April 1999

Matthew Greenhouse (GSFC)
301 286-0596
matt@stars.gsfc.nasa.gov

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NGST Integrated Science Instrument Module (ISIM)

- Overview
  - What is the ISIM?
  - How will it be developed?
  - Programmatics and Schedule
- Community Instrument Studies
- Detector Requirements

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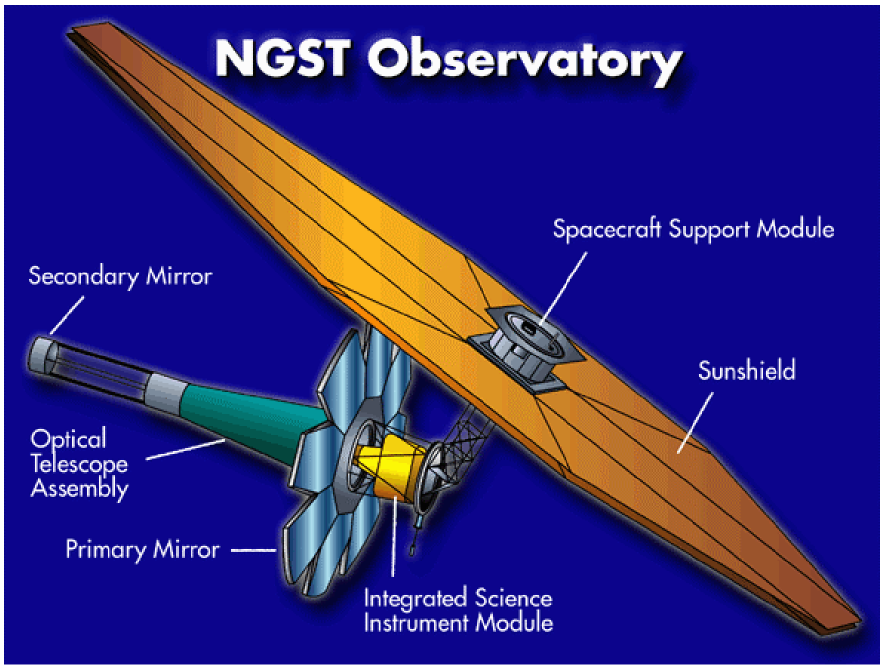
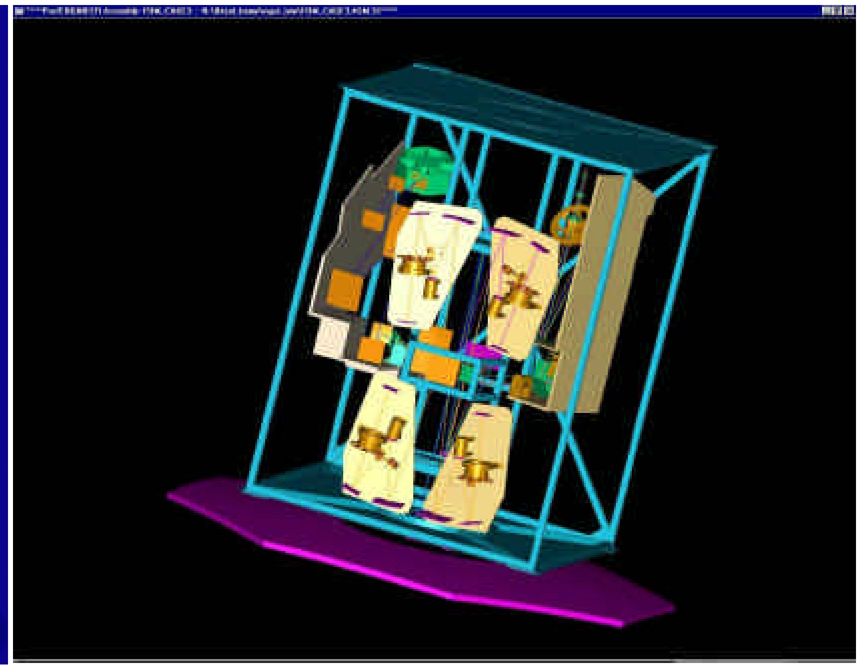
NGST Integrated Science Instrument Module

- One of three major subsystems that comprise NGST
- The ISIM system consists of a cold instrument module and a data system located in the SSM
- The cold instrument module contains:
  - OTA optics
  - US, European, and Canadian science instruments
  - Support systems (thermal, electronic, etc)



NGST Yardstick OTA, ISIM, and SSM



Yardstick Integrated Science Instrument Module

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ISIM Development

- GSFC will lead an IPT for development of the ISIM
  - members include: STScI, ESA, CSA, Prime Contractor, and Flight Instrument PIs
- Science instruments for ISIM procured from US, European, and Canadian science communities and delivered fully qualified to GSFC for integration into ISIM
- ISIM system designed, constructed and integrated at GSFC
  - structure, thermal, electronics systems, data system, flight software, and GSE
  - flight qualified module delivered by GSFC to Prime as GFE

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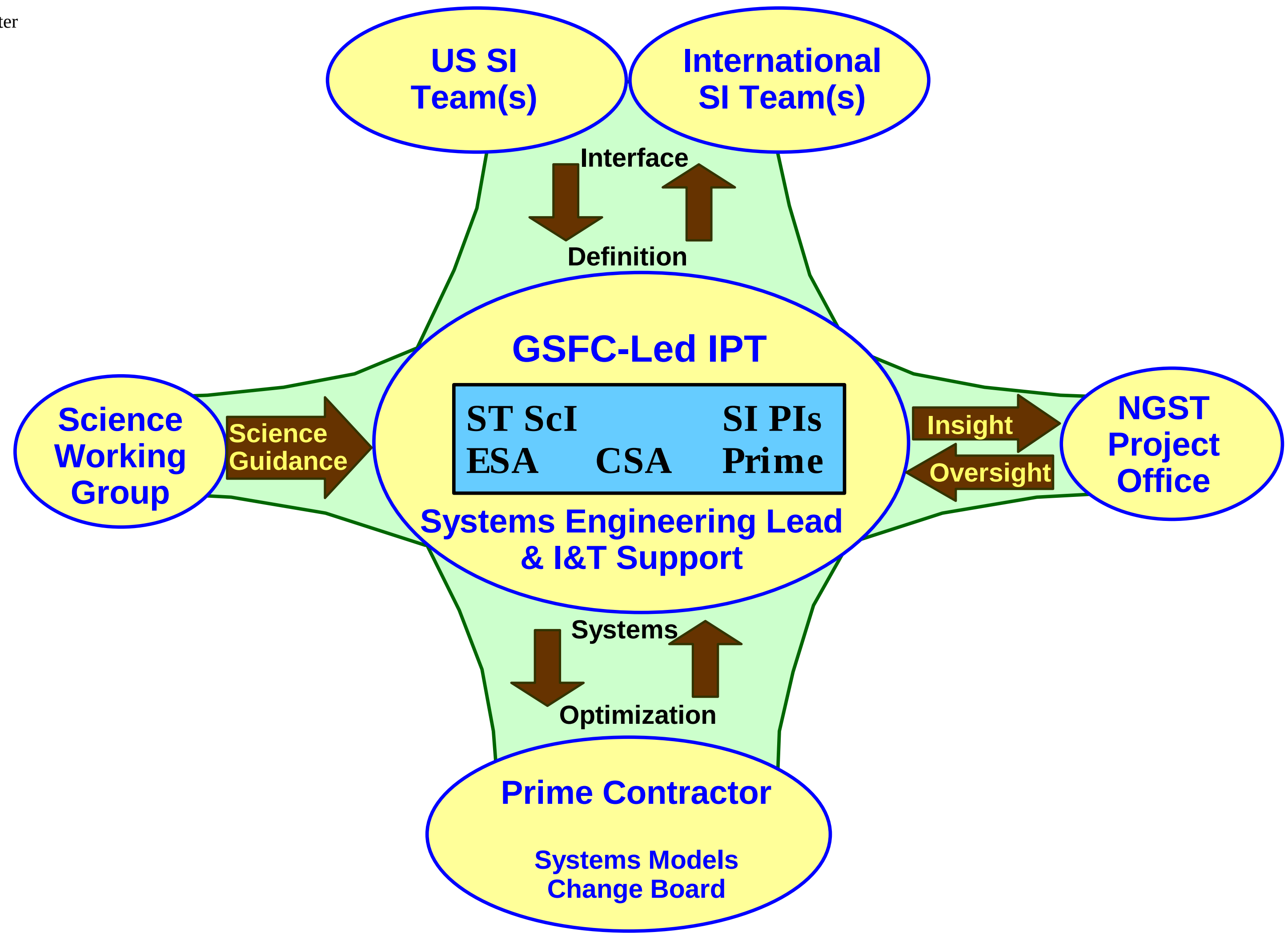
ISIM Development Approach



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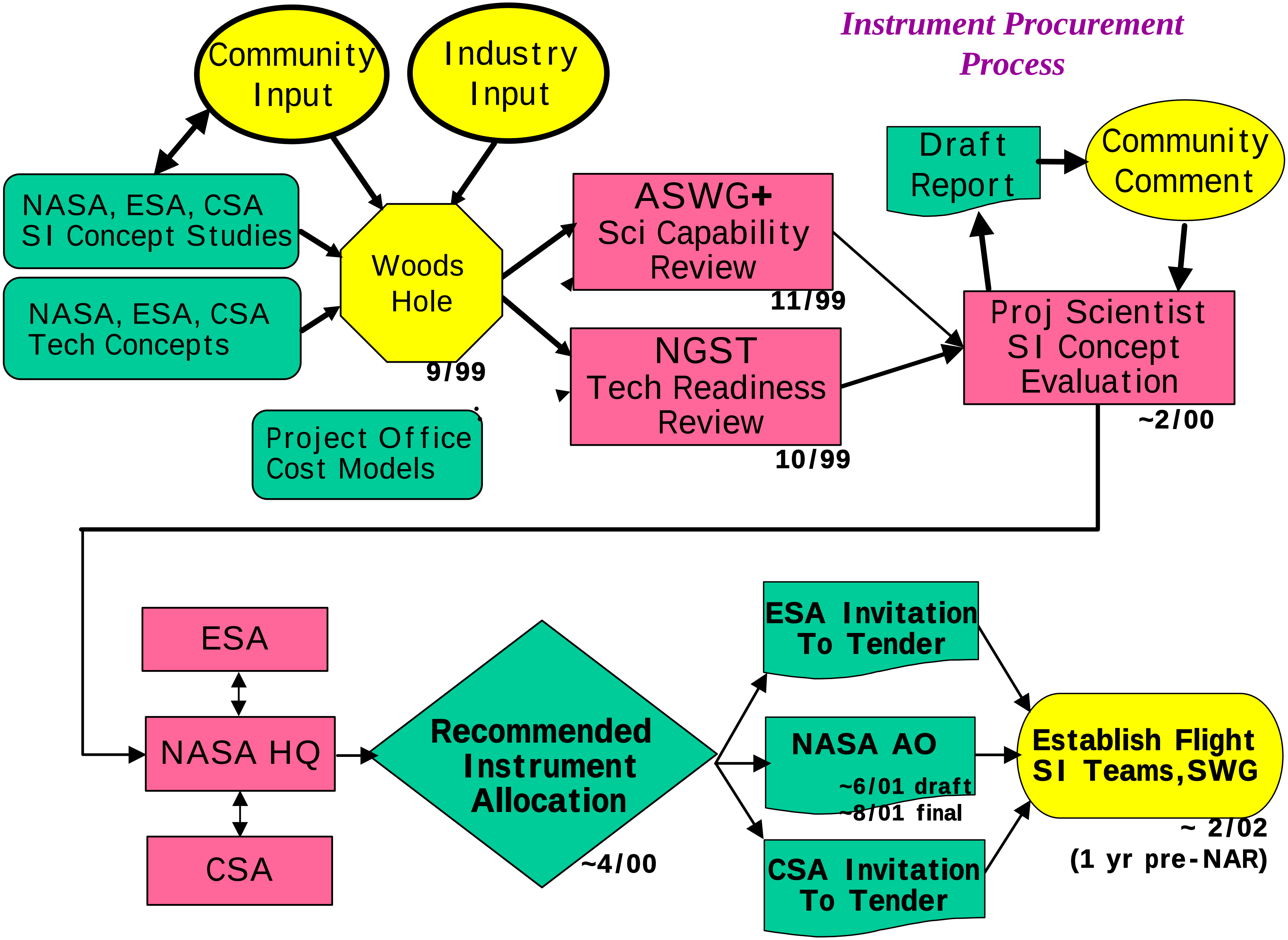
Science Instrument (SI) Procurement Rationale

- GOALS
- Science instrument selection via NASA AO process at mid-formulation phase (2/02)
- close SI concept trade early in phase A to:
  - enable smart customer instrument allocation among NASA, ESA, and CSA
  - enable architecture level system trades to proceed
  - focus ISIM technology development spending to retire risk early
- PROCESS
- process reviewed by: ASWG, SRB, NESR, HQ, SScAC/Origins, as well as ESA and CSA advisory committees.
- prioritization of generic instrument concepts prior to NASA/ESA/CSA allocation
  - science capability: panel includes the Ad Hoc Science Working Group (ASWG)
  - technical feasibility and cost: technical/engineering panel
  - recommendation issued by Project Scientist
    - draft open for public comment (1/00)
- RESULT
- generic SI concepts evaluated prior to inter-agency allocation and AO solicitation
- participation in pre-phase A not a factor in answering AO solicitation



ejs 2/16, after M.Greenhouse, 2/11

Pre-AO Concept Evaluation Process

Science Capability

- Select generic concepts/methodologies for instruments that enable the NGST Phase A science requirements and DRM.
  - wide field imaging and spectroscopy over 0.6 - 10+ microns
  - diffraction limited angular resolution at 2 microns
  - Zodiacal background limited sensitivity over 0.6 - 10+ microns

Technology Readiness

- Assess generic concepts for feasibility and technology readiness relative to NGST development schedule and budget

Project Scientist

- Consolidate science and technical review findings into report
  - draft available for public comment

Inter-Agency Negotiation

- Recommended NASA/ESA/CSA instrument allocation

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Instrument Acquisition Timeline

Instrument Procurement Timeline: Version 3.2							
ISIM Milestones				**Year**	**Month**	**NGST**	**NGST Milestones**
NRA 1: Concept Studies	NRA 1			1998	6	Pre-A	
					7		
					8		
					9		
					10		SRB 2
					11		
					12		NESER
AAS Town Meeting #1				1999	1		
					2		
					3		
Detector Workshop #1					4		
					5		
AAS Town Meeting #2					6		
		Studies Due 1 Aug			7	A	Formulation Phase 1
		Concept			8		
Woods Hole Meeting		Evaluation and			9		
Technical SI Concept Evaluation	NRA 2	Allocation			10		
Science SI Concept Evaluation	Year 1				11		
					12		
AAS Town Meeting #3				2000	1		
Project Scientist Report					2		
					3		
NASA/ESA/CSA Allocation Complete					4		
		Specs	Interface		5		
					6		
ESA Instrument Letter of Commitment					7		
					8		
					9		
	Year 2				10		
					11		
					12		
				2001	1		
					2		
					3		
					4		
					5		
AO Draft Release: Instruments & SWG		DRAFT AO			6		
Pre-Proposal Workshop					7		Single Prime Select
AO Release		AO Solicitation			8		Formulation Phase 2
					9		
Proposals Due	Year 3	AO Peer Review			10	B	
	(final)				11		
					12		
Instrument & SWG Selection Complete				2002	1	on going	
	on going				2		

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NRA 2: Instrument Technologies & Modeling

- Schedule
  - NRA available late May
  - Letters of intent due late June
  - Proposals due early September
- Examples of topics covered by this NRA include:
  - Instrument technologies for multi-object and integral field spectroscopy
  - Conventional and MEMS cryogenic infrared tunable filters
  - Laboratory and ground-based demonstrations of NGST science instrument concepts
  - Laboratory demonstration of long life flight cooling systems for 6 K IR focal plane arrays
  - Techniques for characterization and operation of detectors under ultra-low background conditions.
  - Modeling and simulations relevant to enhanced understanding of NGST instrument requirements

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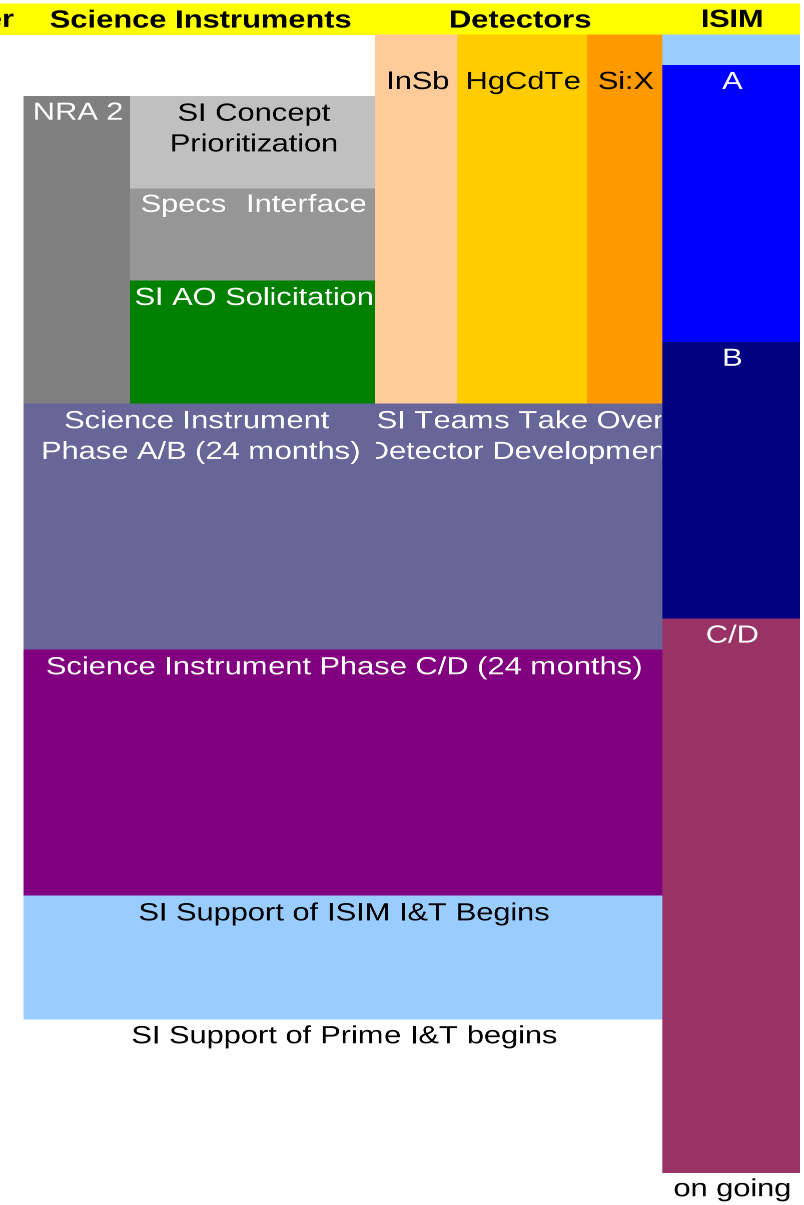
US Instrument Development Timeline

US Instrument Development Timeline: Version 3.1

ISIM Development Milestones	Year	Quarter
1st Community Workshop on Detectors	1999	2
Woods Hole Meeting		3
		4
Code S Detector Funding 3 Yr Cycle	2000	1
		2
		3
2nd Community Workshop on Detectors		4
	2001	1
		2
Single Prime Select		3
		4
Instrument & SWG Selection Complete	2002	1
		2
		3
		4
SI PDR, NGST NAR	2003	1
		2
		3
Observatory Phase C Start		4
SI CDR	2004	1
Observatory CDR		2
		3
		4
Flight Detector FPAs Delivered To SIs	2005	1
		2
		3
		4
	2006	1
SIs Delivered TO GSFC (L - 25 months)		2
		3
		4
	2007	1
ISIM Delivered To Prime (L - 15 months)		2
		3
		4
	2008	1
		2
Launch		3



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US Community Instrument Concept Studies

Solicited from external community via NASA HQ NRA
Six teams, selected during Jun 98
Final reports due Aug 99
Public oral reports at Woods Hole meeting during Sep 99

- J. Bechtold, T. Greene: U. of Arizona & Lockheed Martin Corp.
  - 0.3 - 40 micron imaging, spectroscopy, and ISIM layout
- J. Graham: U. of California & ITT Industries & Lawrence Livermore Labs
  - 1 - 15 micron Fourier transform imaging spectroscopy
- J. MacKenty: STScI/ Ball Aerospace/ GSFC
  - 1 - 5 micron multi-object spectroscopy with MEMS micro-mirrors
- H. Moseley: GSFC
  - MEMS micro-shutter aperture control for multi-object spectroscopy
- G. Serabyn: JPL
  - 5 - 28 micron camera/spectrometer and Sorption cryo-cooler
- J. Trauger: JPL
  - 5 - 30 micron high contrast coronagraph with deformable mirror

Details of these projects and mid-term poster presentations are on the ISIM web site: http://www701.gsfc.nasa.gov/isim/isim.htm

CSA NGST Science Instrument Studies

Three science instrument studies are underway in Canada

1. Near-IR MOS/IFS:

   David Crampton (HIA/DAO) + CAL (Ottawa)

2. Visible Imager:

   Paul Hickson (UBC) + CAL (Ottawa)

3. IFIRS Imaging FTS:

   Simon Morris (HIA/DAO) + Bomem(Quebec)
   (collaboration with US Graham/ITT study)

Instrument Concept Studies

- Consortium selected by ESA to perform a trade study of integral field and multi-object spectrograph options
  - O. Le Fevre (PI), LAS, Marseille, France
  - R. Bacon, Observatoire de Lyon, France
  - R. Davies, Durham University, UK
  - R.S. Ellis, Cambridge University, UK
  - G. Monnet, European Southern Observatory, Garching, Germany
  - N. Thatte, MPE, Garching, Germany
  - T. de Zeeuw, Leiden Observatory, the Netherlands
- An image slicer IFS design has been selected for detailed study.
- Optical camera study underway: Martin Ward et al.
- Payload suite study encompassing OTA, ISIM, and instruments awarded to Dornier Satellitensysteme (Munich, Germany) & Alcatel (Cannes, France)
  - - a wide field filter wheel camera covering the VIS/NIR wavelength range (0.6 - 5 µm)
  - - a wide field Fourier Transform Spectrograph, doubling as Wide Field Camera (VIS/NIR)
  - - a MIR camera covering 5 µm - 10 µm and 10 µm - 28 µm (TBC)
  - - a MIR Integral Field Spectrograph covering 5 µm - 10 µm and 10 µm - 28 µm (TBC)

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GSFC Baseline ISIM Design Study

- Study goals:
- Demonstrate mission science feasibility,
- Assess ISIM engineering and cost feasibility,
- Identify ISIM technology challenge areas,
- Enable smart customer procurement of NGST.

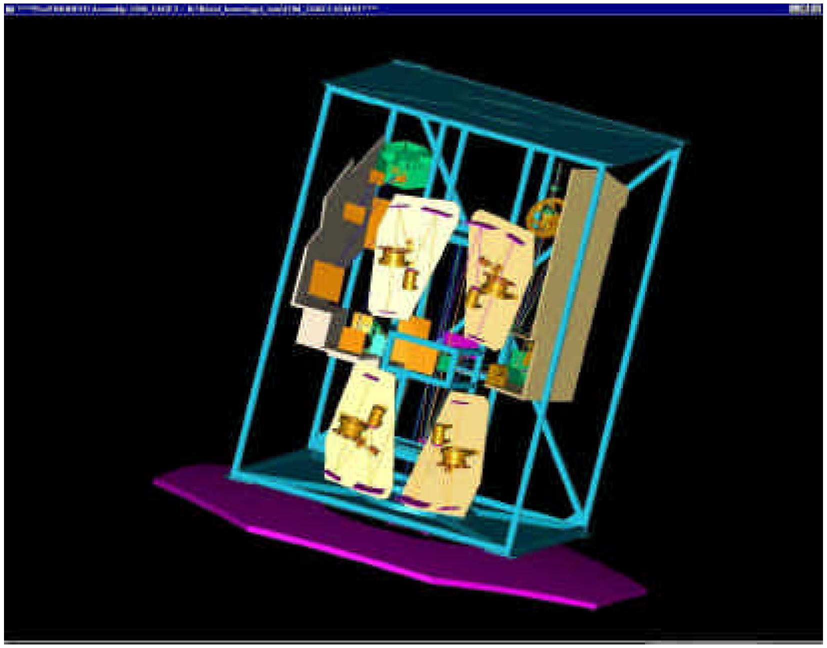
- Architecture constraints:
- Integration with the "Yardstick" and other NGST 8 m architectures that are intended for packaging in an EELV or Ariane 5 meter class fairing.

- Ongoing progress can be monitored via the ISIM web site:
  – http://www701.gsfc.nasa.gov/isim/isim.htm

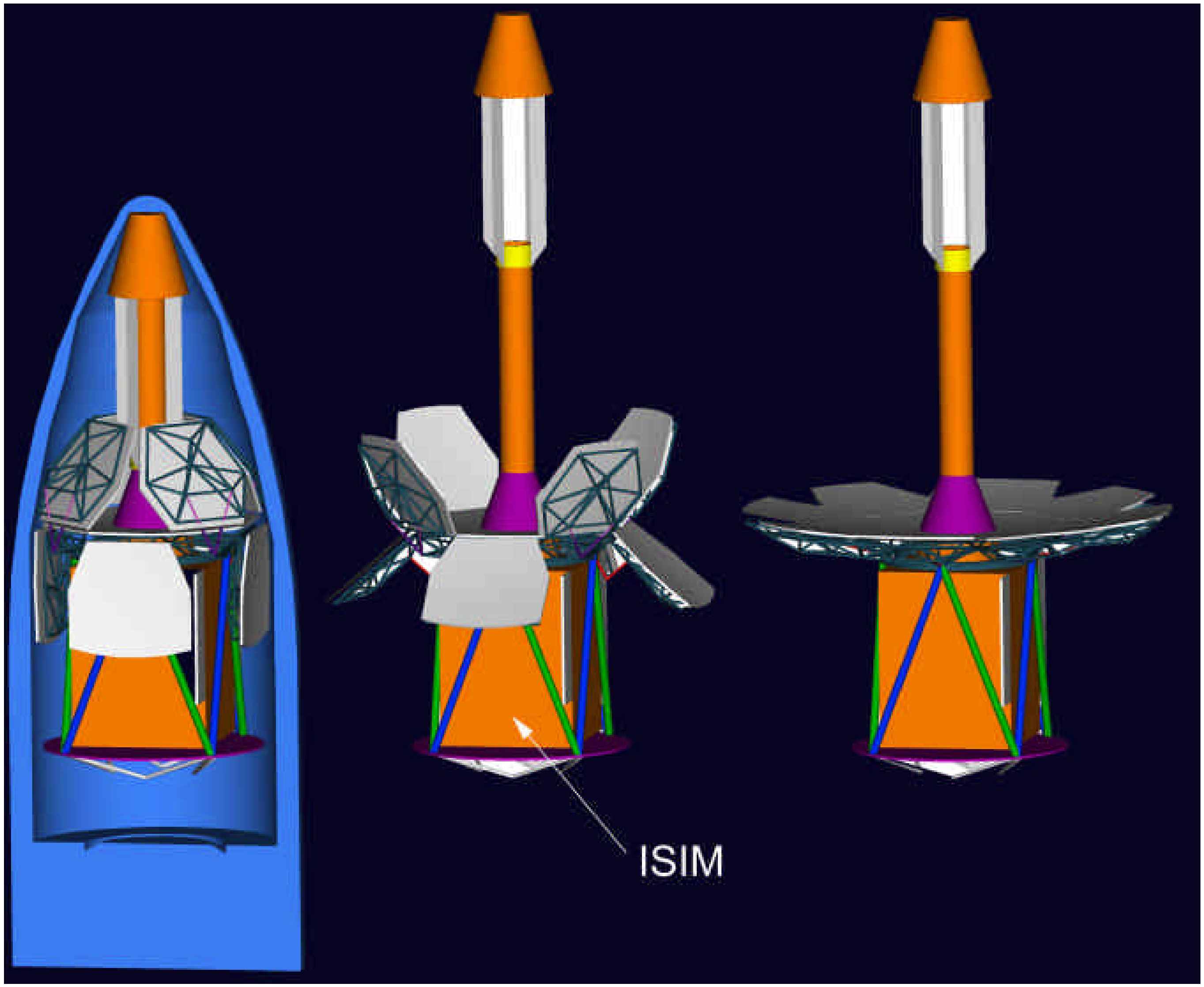
Baseline ISIM Design Evolution

- 1996
  - single integrated instrument
  - top level concept only

- 1999
  - modular instrument
  - detailed engineering model
    - opto-mechanical layout
    - structural design
    - thermal system design
    - data system and electronics design
    - OTA interface constraints
    - instrument technical constraints
  - procurement plan
  - development schedule
  - detailed cost estimate



NGST 8m: EELV Medium 5m Fairing



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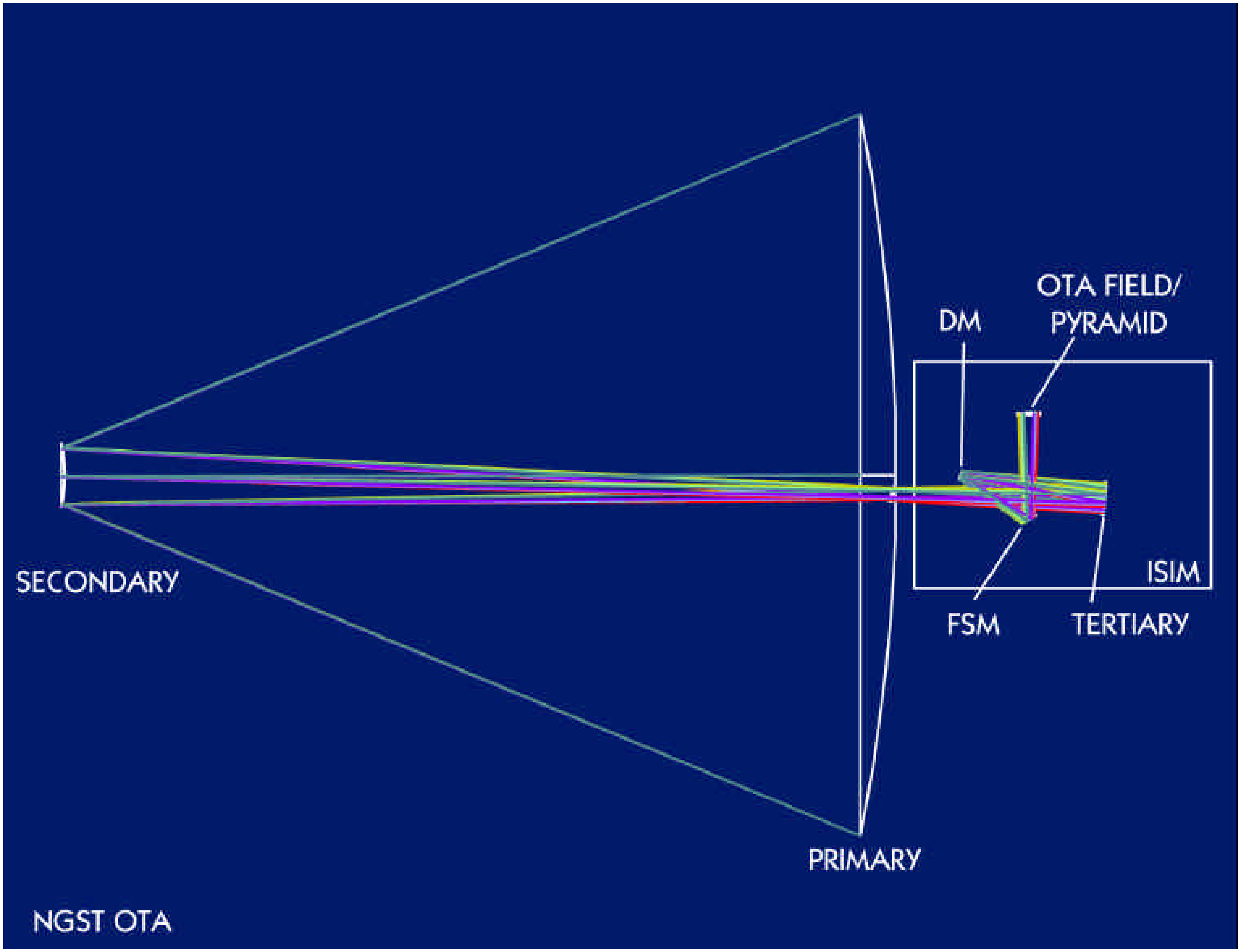
OTA and ISIM System Optical Schematic



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ISIM Baseline Science Instruments

Instrument	Wavelength (µm)	Bandwidth	FPA	Pixel Pitch	Plate Scale (10^{-3} arc-sec)	Aperture Control (arc-min)
Near-IR Camera (1 of 4[1])	0.6 – 5	R = 2,5 fixed filters R = 50,200 tunable filters	4096 x 4096	27	29	quad-beam divider: four 2 x 2 fields
Near-IR Spectrometer	0.6 – 5	R = 300, 3000 gratings	4096 x 4096	27	100	reflective slit mask: 2048 x 2048 micro-mirror array, 100 µm pixels
Mid-IR Camera/Spec	5 – 28	broad-band filters grisms, cross-disperser	1024 x 1024	27	230	slit selection + 2 x 2 camera

1. A quad-beam divider (pyramid mirror) apportions a 4 x 4 arc-min field of view over 4 identical cameras.

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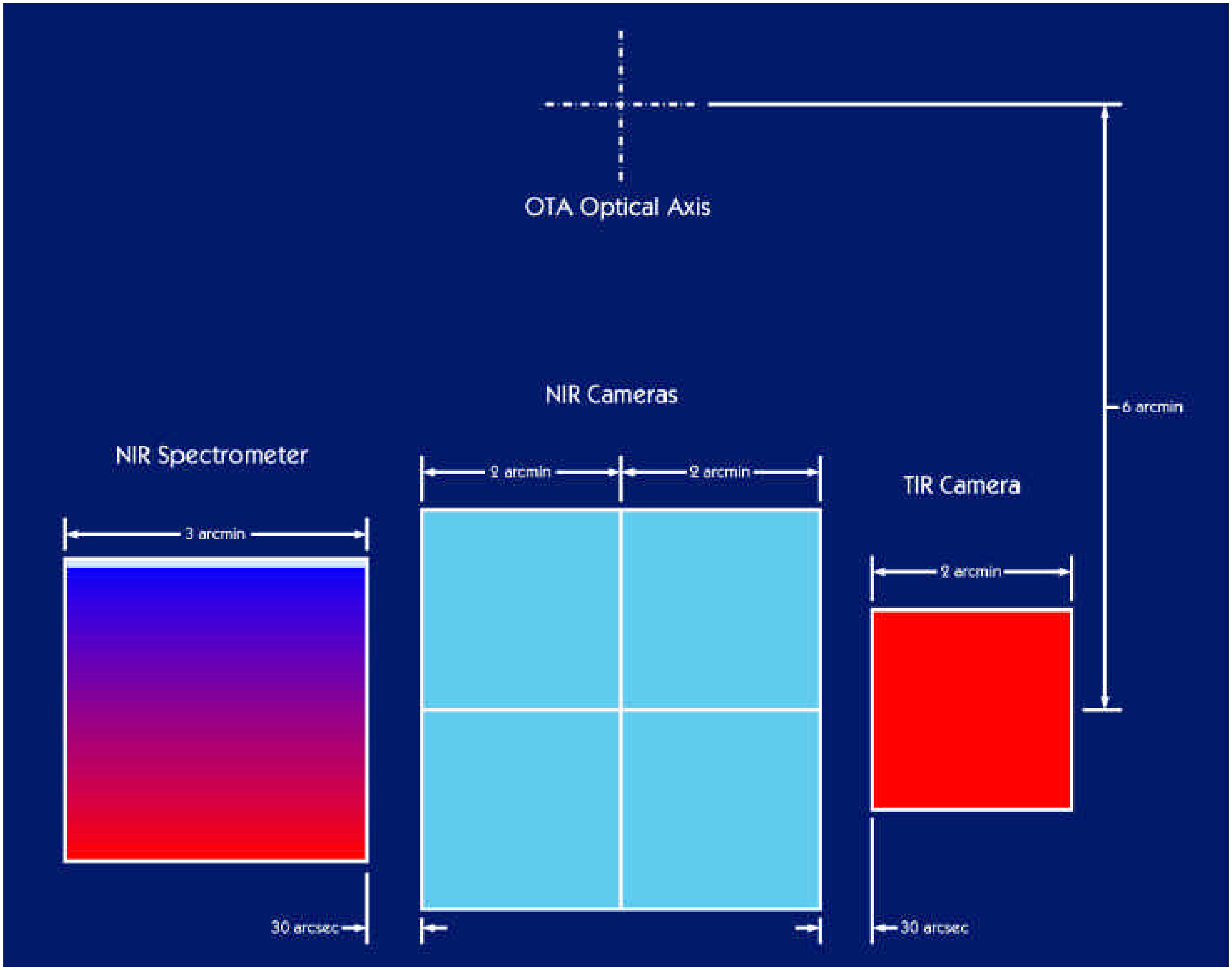
NGST ISIM Focal Plane Layout



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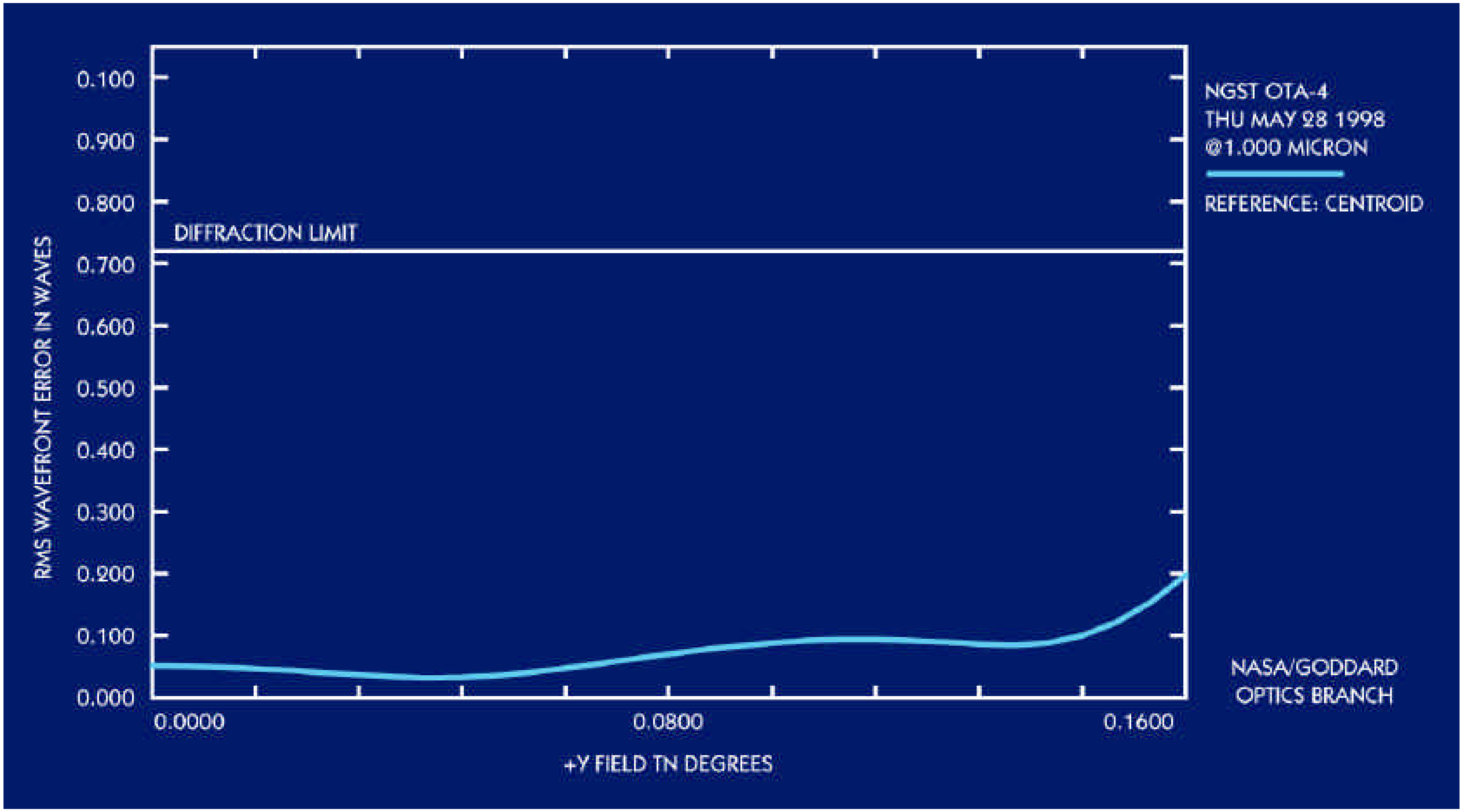
RMS Wavefront Error Vs Field Position



The ISIM instruments are located in an off-axis position.

This configuration yields excellent image quality over a 24 arc-min diameter field.

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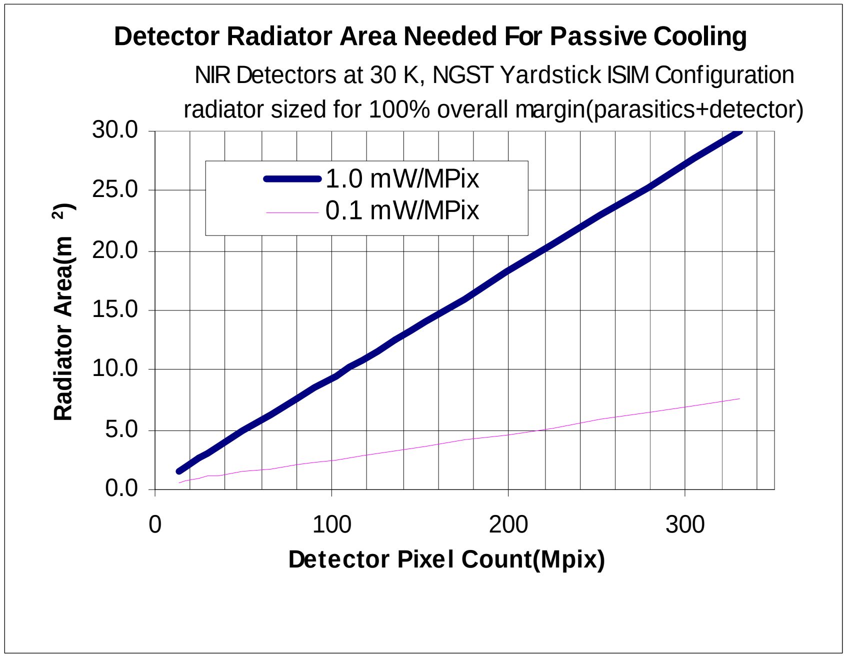
Only a small portion of the available OTA focal plane is utilized by the Yardstick instruments

- Limited by size of detector complement
- Yardstick detector complement consists of 84 Mpixel NIR and 1 Mpixel MIR
- Limiting factors on detector complement include:
  - cost feasibility
    - detectors
    - system cost factors
      - data system
      - thermal system
    - see data system poster
  - technical feasibility
    - power dissipation
      - detectors
      - front-end electronics
        - » Yardstick: 10 W



SIRTF InSb = 2 mW/Mpix

FPA requirements of NIR wide field camera illustrate NGST detector challenge

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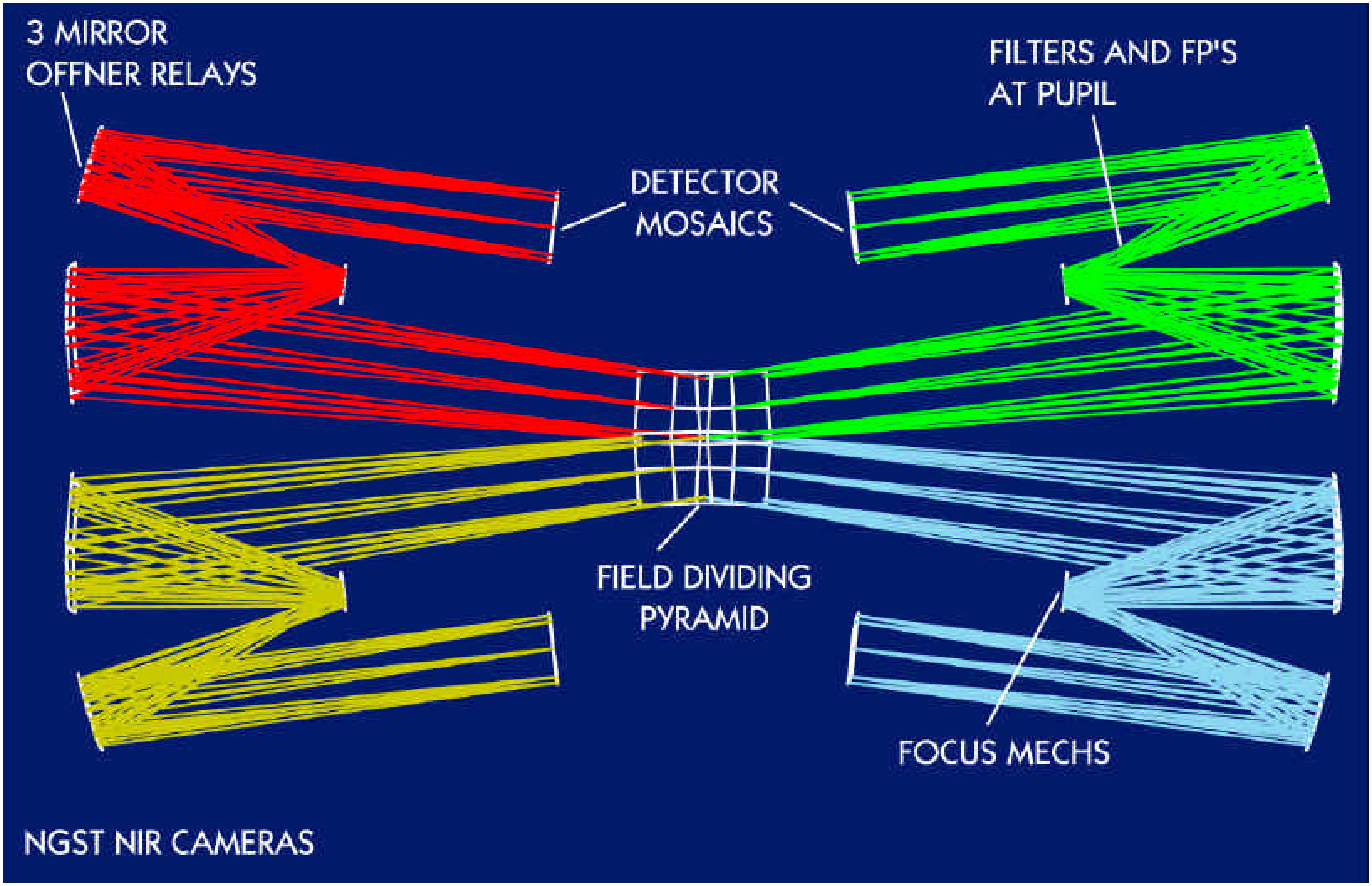

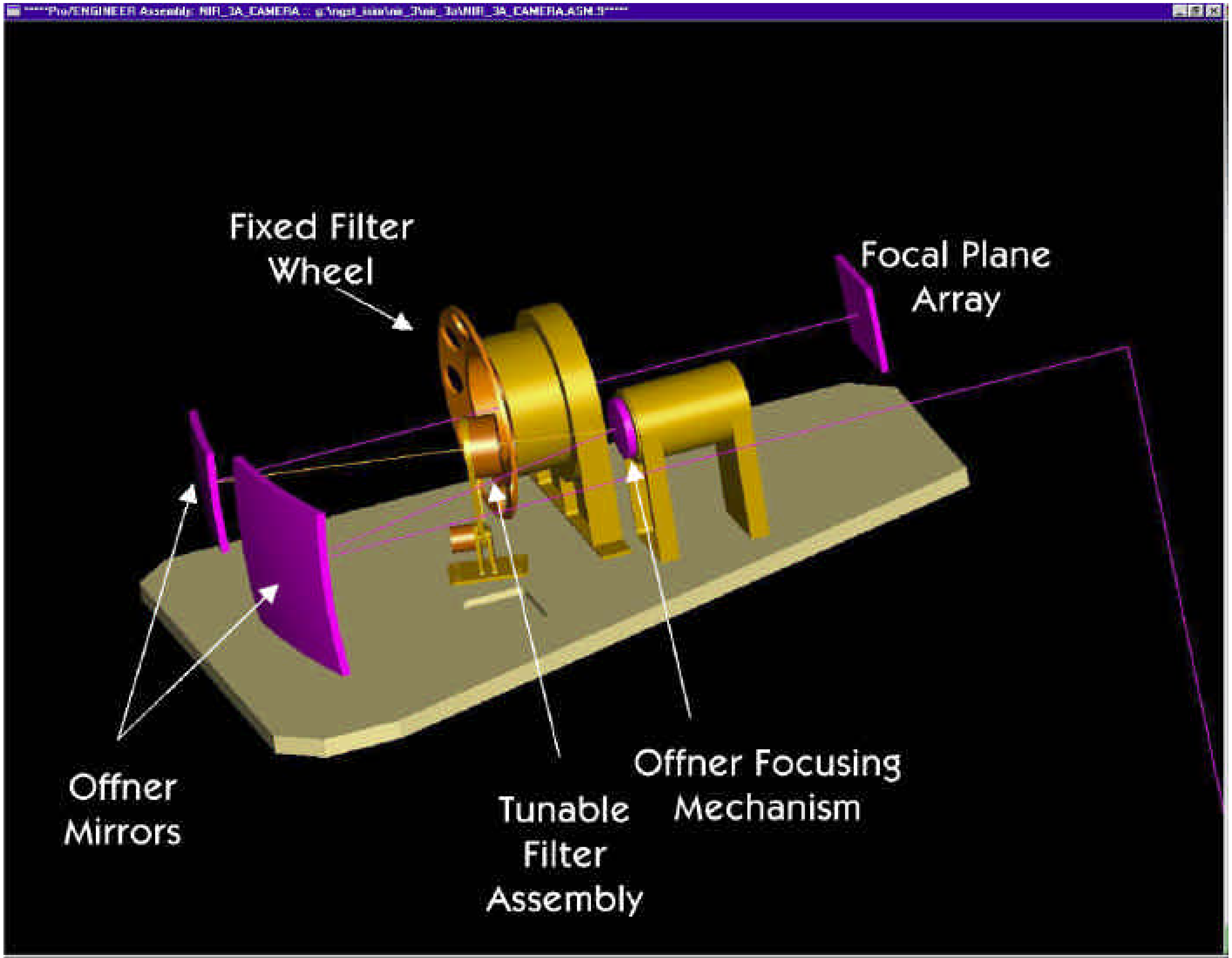

Each camera channel includes a focusing Offner relay, filter wheel, and retractable tunable filter.

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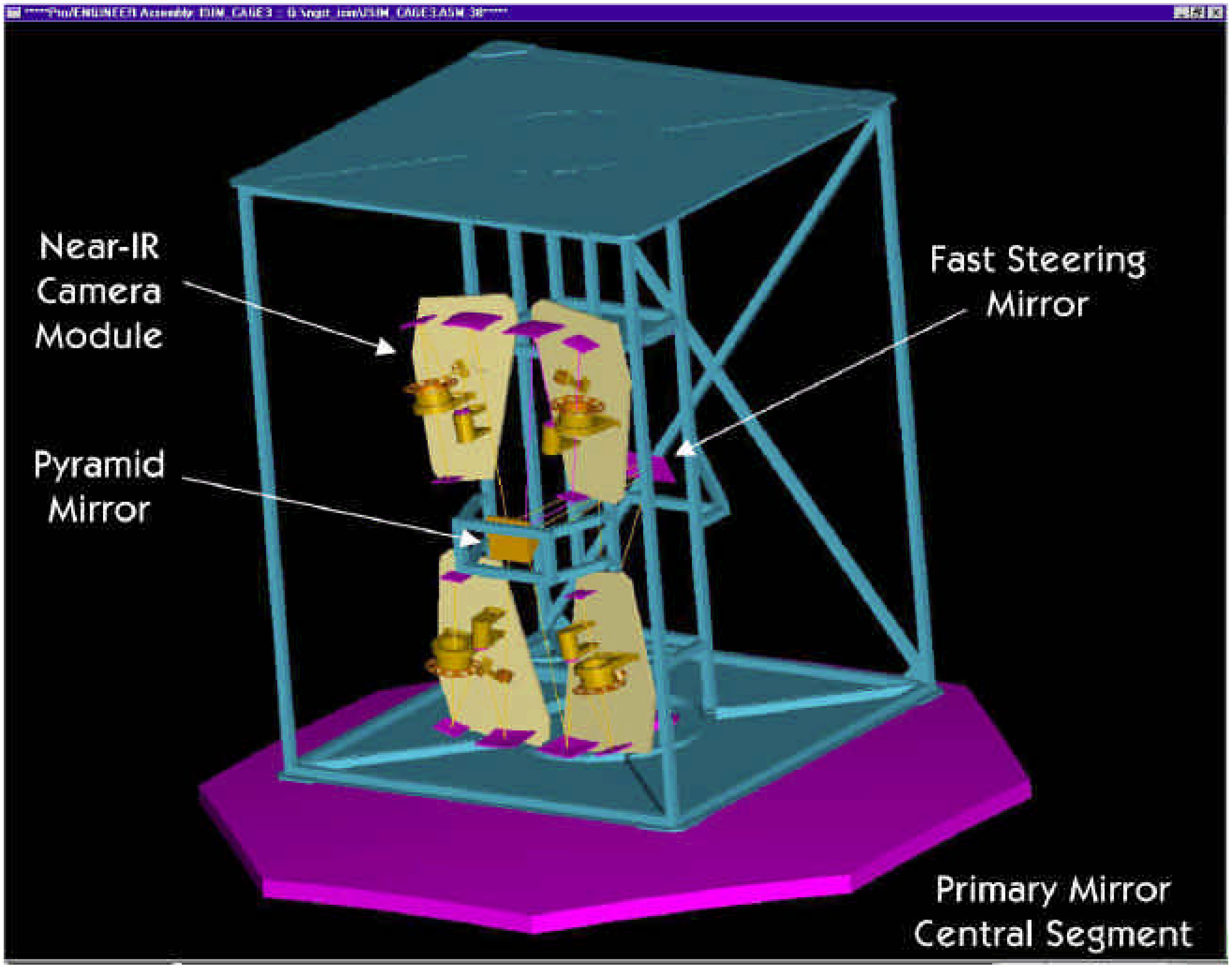

The ISIM near-infrared wide field camera employs a pyramid beam divider to apportion a 16 square arc-min field of view over four identical camera modules. Each module utilizes a 4096 x 4096 focal plane array covering 4 square arc-min.

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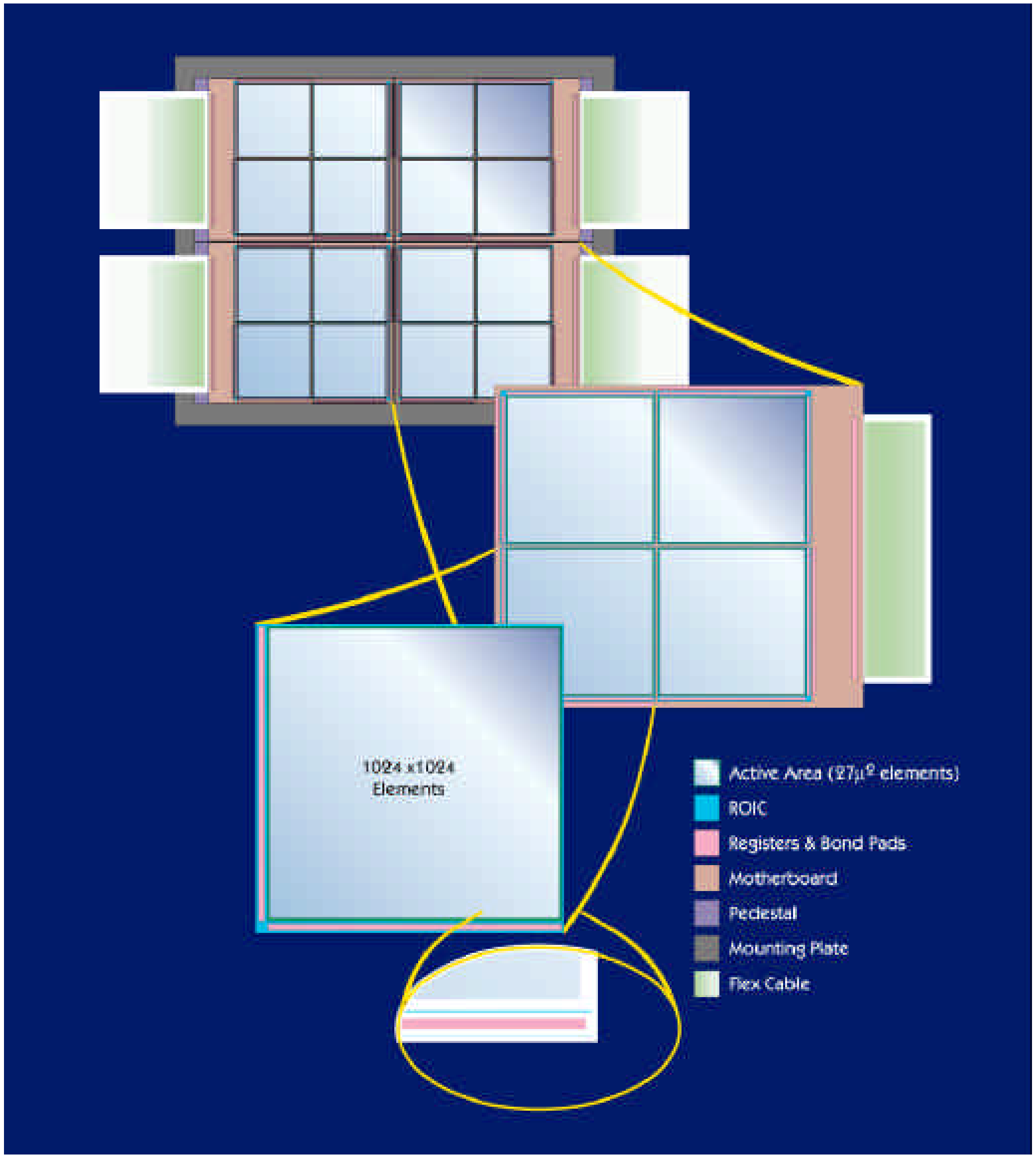
4096 x 4096 Near-IR FPA Assemblies



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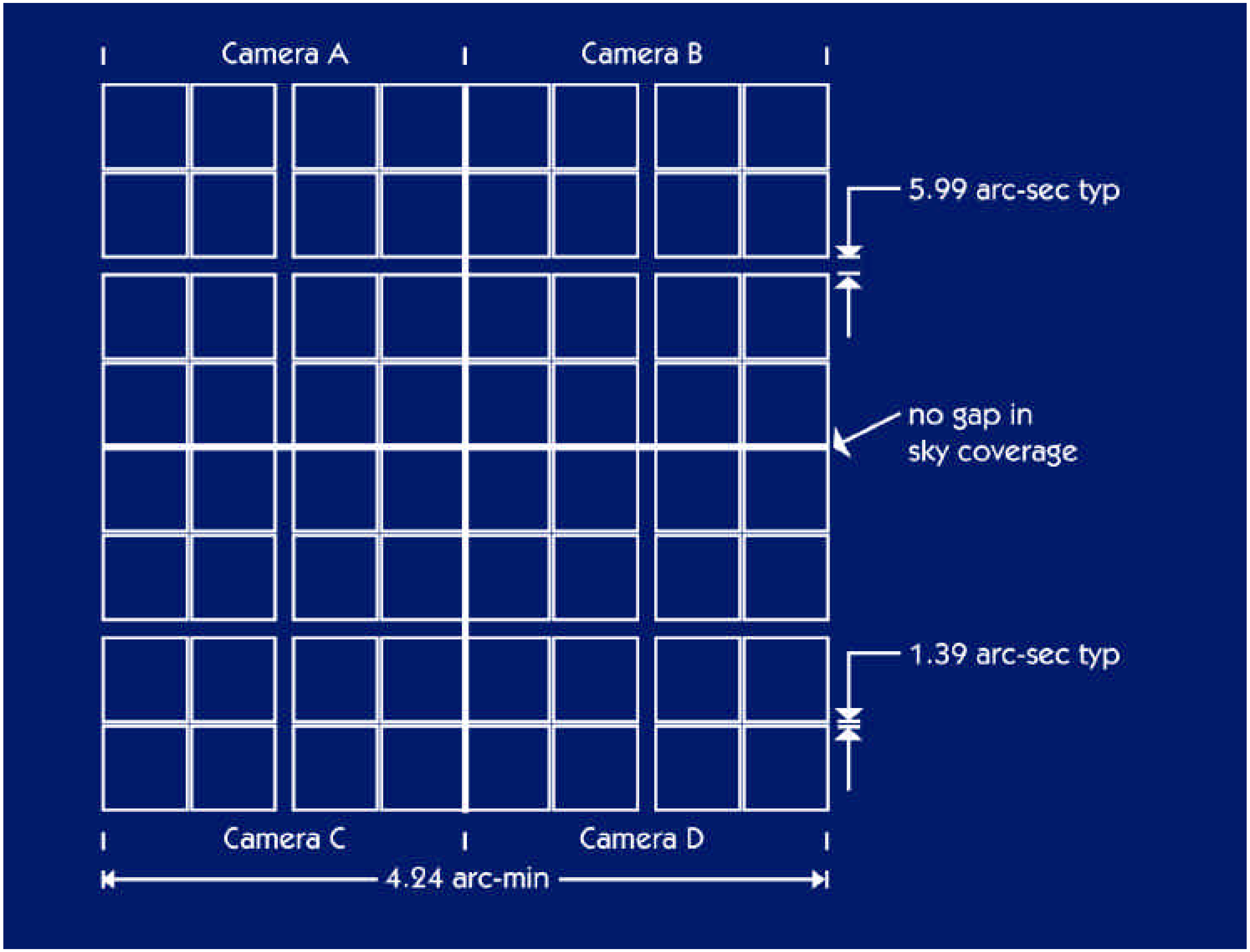
Near-IR Quad-Camera FOV



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Incremental Development Is Needed To Meet Detector Goals

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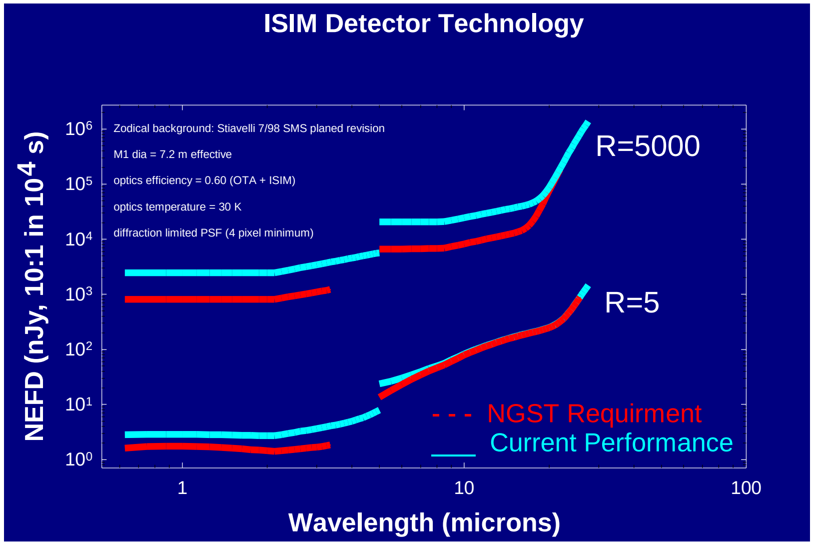
Challenge areas:

5x reduction in read noise
10x reduction in dark current
FPA packaging & SCA yield

	T (K)	QE	Read Noise (e) multiple	Dark Current (e/s)
SIRTF InSb	15	0.9	7	0.1
NIR goal	30	>0.9	<1.5	<0.01
SIRTF Si:As	6	0.6	8	1
MIR goal	8	>0.8	<1.5	<0.01



Detector Development Programs Underway

l (mm)	T (K)	Investigators	Technology	SCA format
0.6 – 5	30	U. Rochester & Raytheon IRCoE	InSb	1024
0.6 – 5	30	U. Hawaii & Rockwell Science Center	HgCdTe	2048
0.6 – 5	30	Ball Aerospace & Raytheon IRCoE	ROIC for InSb	2048
5 – 28	6 - 8	ARC & Cornell U. & Raytheon IRCoE	Si:As	512
5 – 18	10 - 12	Boeing Research and Technology Center	Si:Ga	1024
5 – 10	30	U. Rochester & Rockwell Science Center	HgCdTe	single diode tests

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Yardstick Requires Five 16.8 Mpixel Near-IR FPAs

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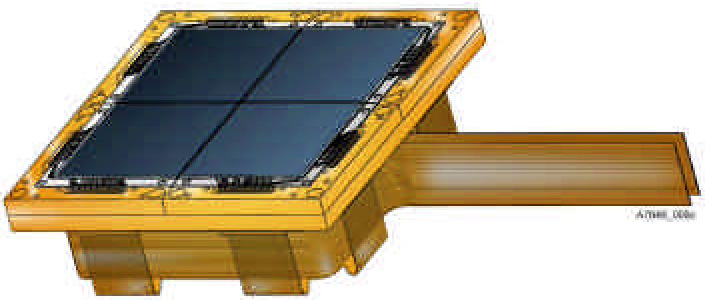
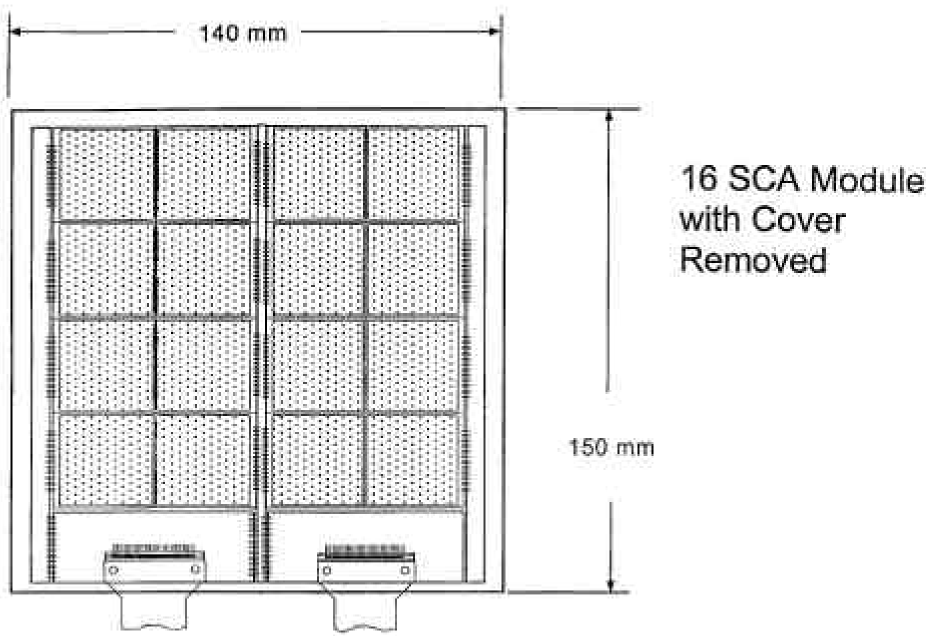
FPAs built up from smaller SCAs

SCA format options: 1k, 1.4k, 2k

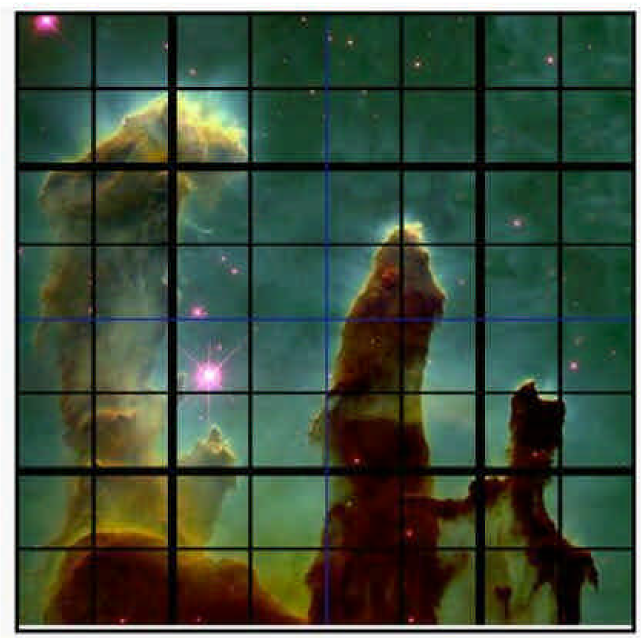
Both InSb & HgCdTe options for 0.6-5 μm



Ball Aerospace concept



Raytheon IRCoE concept



J. Hester, P. Scowen (ASU) & J. Morse (U.CO)

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Baseline Requires One 1 Mpixel Mid-IR FPA

SCA format options: 512 or 1024

- Si:As is high readiness option: 5-28 µm, 6-8 K
  - SIRTF heritage
  - Several flight cryo-cooler options: Brayton, Sorption
    - -- 6 K Brayton cooler demonstrator expected during Oct 99
  - Solid H open cycle cooling possible with issues:
    - -- lifetime, weight, T < 8 K challenging

- Si:Ga is speculative option: 5-18 µm, 10-12 K
  - Materials development underway
  - Operating temperature more compatible with solid H than Si:As

- HgCdTe is speculative option: 5-10 µm, 30 K
  - Characterization underway
  - Dark current requirement is challenge area for this technology
  - Compatible with radiative cooling

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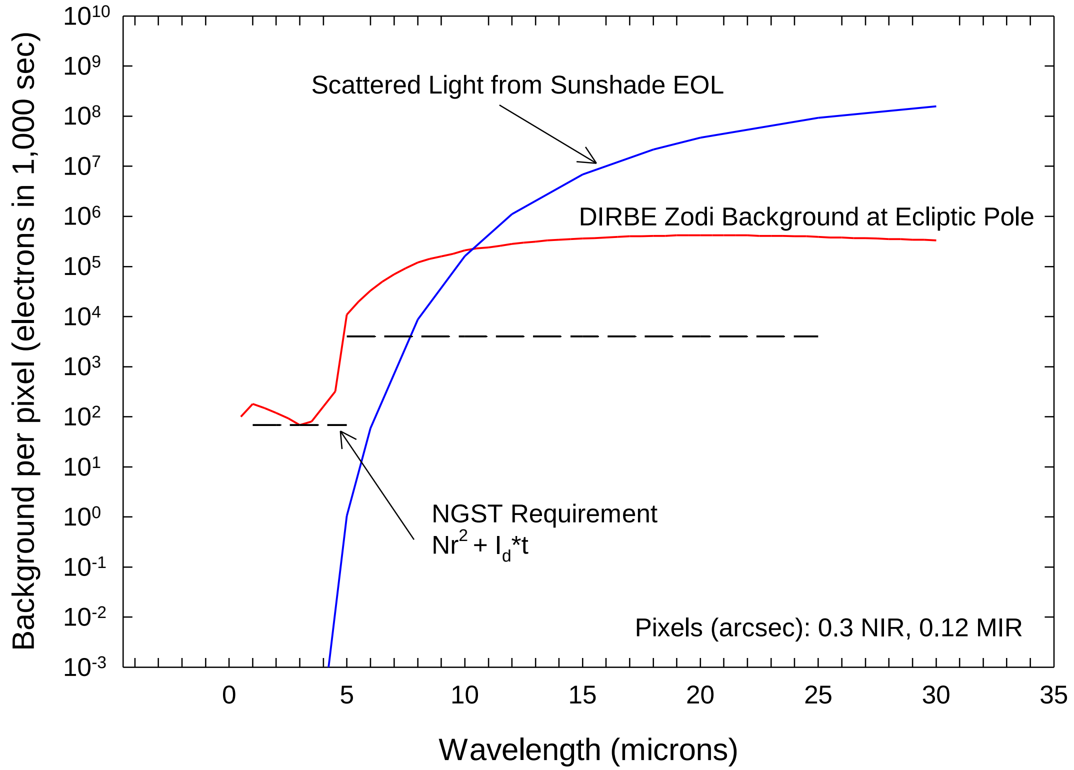
Detector Format Requirements

- Factors governing choice of SCA format: the why 2 k issue
  - FOV gaps
    - DRM provides no strong discriminator for 1 - 2 k options
      - grating spectroscopy exception
    - Operations impact of gaps not yet studied
  - Baseline fine guidance approach may place extra requirement on 2 k SCA
    - would need science grade performance from portion of SCA outside of 10 pixel guide window
  - Cost
    - number of SCAs vs process yield
- Conclusion:
  - Desired SCA format open to discussion
  - Current NGST requirements on format limited to FPA
    - 4096 near-IR, 1024 mid-IR

Detector Noise Requirements

NGST BLIP at 20% Bandpass



Detector Noise for BLIP in 1000 s @ various l and R		
$[N_r^2 + (I_d * 1000)]^{1/2}$	3.0 μm	5.5 μm
Requirement: e / R	8.4 / 5	63 / 100
Goal: e / R	3.9 / 100	20 / 1000

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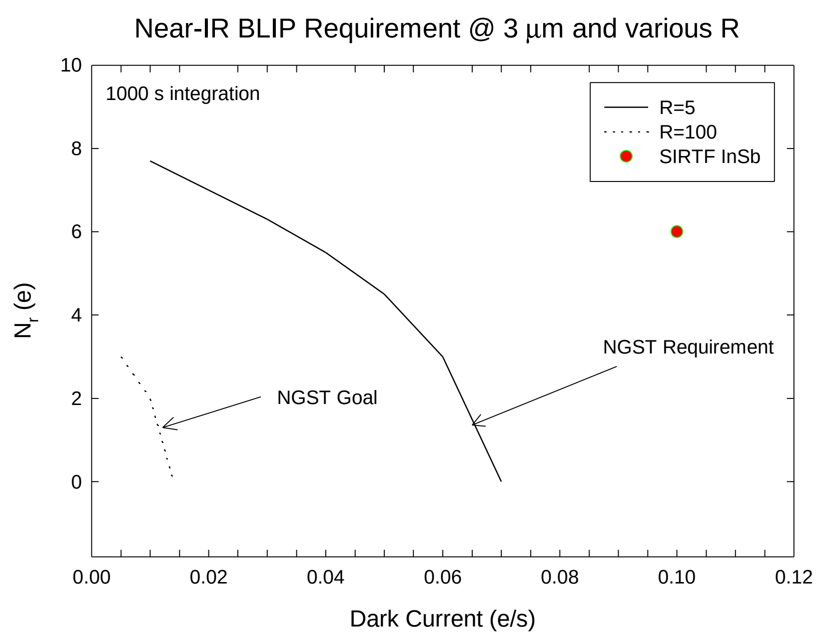
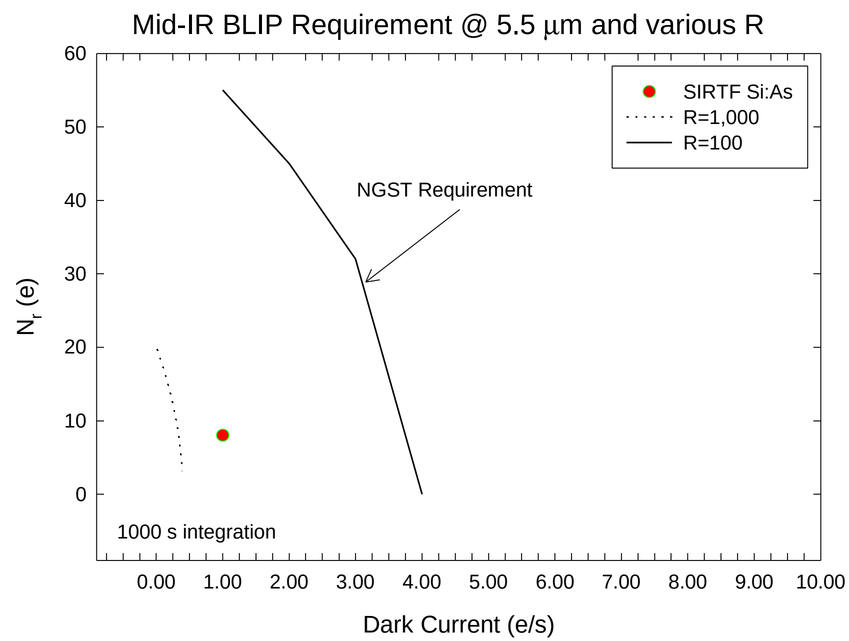
Read Noise & Dark Current

Apportioning total noise requirement over N_r and I_d open to discussion

Cosmic ray limit on maximum integration time open to discussion





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ISIM IPT During NGST Phase A (July 99)

- During Pre-Phase A, GSFC performed a detailed engineering study of an ISIM for the Yardstick observatory architecture.
  - http://www701.gsfc.nasa.gov/isim/isim.htm
  - community feedback welcome
- During Phase A, the ISIM IPT will evolve this design in two directions to integrate with two competing Prime Contractor NGST architectures.
  - GSFC will develop two proprietary designs
  - IPT working relationships (GSFC, Primes, STScI, ESA, CSA) fully formed for:
    - smooth transition to Phase B
    - smart customer insight for mid-Phase B down select

See Posters for Additional Information

- ISIM Overview
  - covers aspects beyond those discussed here
- Data System
  - approach to detector readout
  - limitations on size of detector compliment
- Instrument Procurement Plan
  - NRA and AO schedules
  - programmatics
- This chart set available on ISIM web site
  - http://www701.gsfc.nasa.gov/isim/isim.htm

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